FORD and ROSS, under the supervision of Professor LEUSCHNER, and have now turned the whole work over to the latter to be completed and prepared for publication. The work is being carried on under the auspices of the National Academy of Sciences, and the present Watson trustees are: Professor SIMON NEWCOMB (chairman), Professor LEWIS BOSS, and Professor W. L. ELKIN. It is their intention to have all the results published in due time. It has, however, seemed fitting upon this occasion to offer to those interested in the Berkeley Astronomical Department this brief statement of our connection with the undertaking.

THE PHOTOGRAPHIC EQUATORIAL OF THE STUDENTS' OBSERVATORY.

By ALLEN F. GILLIHAN.

(Read before the meeting of the Society, held in Berkeley, January 30, 1904.)

It has been demonstrated by Professors BARNARD, WOLF, and others, that lenses of the portrait type, and of large aperture, on account of their great light-grasping power, are very suitable for obtaining, with long exposures, photographs of very faint stars. Such a lens has been in the possession of the Students' Observatory for some years, but for lack of a suitable mounting, little work could be done with it. From time to time, however, it has been strapped to the tube of the 6-inch equatorial, together with its wooden camera, but as, until recently, the driving clock of this instrument did not perform well, and as there was no slow motion in hour-angle, this mounting was entirely unsuitable for photographic purposes. The need for a suitable mounting was thus greatly felt, particularly so in connection with the department's work on the Watson asteroids, it being the intention to verify by photographic observations their computed positions before tables for these asteroids are constructed.

Correspondence with various instrument-makers developed the fact that a mounting such as was desired could be constructed only at a greater loss of time and cost than seemed desirable. The department, therefore, decided to attempt the construction of a suitable equatorial mounting here in Ber-

keley, and after some study of various mountings the regular Fraunhofer model was selected.

In designing the instrument the special purpose for which it was to be used was kept constantly in mind, the object being to construct an instrument of the utmost efficiency for photographing with short-focus lenses, with a powerful and accurate driving-clock, efficient slow motion in hour-angle to control the clock, with all necessary adjustments to facilitate guiding in the dark, and with simplicity and solidity of mounting. It was also necessary to keep the cost at a minimum.

The design of our 6-inch equatorial being both simple and substantial, was used as a model, objectionable features being eliminated and necessary improvements added. One of the special features of the photographic equatorial is, that the frame has been made very compact and heavy, and in as few parts as possible. The clock has been put in a case with glass doors, situated between the equatorial head and the cast-iron column, where it will be protected from dust and moisture. The case needs to be opened only to regulate the pendulum or to oil the clock, but not to wind it. The starting and stopping mechanism is controlled from the outside of the case by means of a button on the north side of the pier. Considerable expense was saved by using commercial gear-wheels in the clock. The teeth of these wheels appear to be very evenly spaced, but the central hole in each wheel had to be recut, as every one was eccentric.

The governor is YOUNG's double pendulum, which is much used in modern instruments on account of its sensitiveness, even action, and freedom from variations due to changes in temperature or to moisture. An important feature in the clock is, that it requires about forty-five to fifty pounds' weight on the drum to make the governor revolve at the proper speed when it is not connected with the instrument; while with the governor removed and the clock connected with the instrument, it requires only about five or six pounds to drive the instrument; that is, the ratio of the weight required to drive the governor to the weight required to drive the instrument is about as seven or eight to one. When, therefore, an extra camera or other weight is added to the instrument, it will make very little, if any, difference in the speed of the governor. The

clock is provided with maintaining power, and under the present arrangement will run for over three hours with one winding.

Another important part is the worm and worm-wheel, which were cut in the Mechanical Department of the University, the worm-wheel having 480 teeth, and the worm revolving once in three minutes. Mr. G. W. RITCHIE, in the *Astrophysical Journal* for November, 1901, in describing the photographic reflector constructed at the Yerkes Observatory, stated that after the instrument was assembled the worm and worm-wheel were ground together with emery flour and oil for a period of 200 hours, and afterwards polished. To this he ascribes the smooth running of the instrument. In our instrument the worm was connected by pulleys and belting directly with the driving-shaft in the workshop in such a way that when the shaft was revolving the worm-wheel, which under the influence of the driving-clock would revolve once in twenty-four hours, was made to revolve in forty-five seconds. The wheel and worm were ground together, using emery flour and oil, for nearly thirty-three hours, making over 2,600 revolutions of the worm-wheel, which at ordinary speed would be equal to about seven years' continuous running. The oil and emery were then removed, and the wheel and worm were polished, running at the same speed, using oil and rouge, for over four hours, which is equivalent to 340 turns, or nearly one year, of continuous running. In this way any irregularities were ground out, and the worm was firmly seated in the worm-wheel, where it is held in close contact by means of a strong adjustable steel spring.

The slow motion in hour-angle is introduced between the driving-clock and the worm. It is a differential gear or mouse control worked by an endless cord in the hand of the observer. Tangent-screw hour-angle slow motion brought to the eye-end of the instrument by gears is expensive, and besides has limited range; the observer is very liable to jar the instrument in moving the handle. None of these disadvantages prevail with the mouse control; while guiding the observer need not touch the instrument, except in case of a comet moving rapidly in declination. In this event, however, very accurate driving is not essential.

Clamp in hour-angle, clamp and slow motion in declination, are brought to the eye-end as in other instruments. Both slow motions are made particularly delicate, for use with a high-power eye-piece. Four feet six inches of the hour-angle slow-motion cord moves the instrument through one minute of time, and one turn of the declination slow-motion handle corresponds to four minutes in declination.

The declination-sleeve has been made unusually long, and with the circle partly counterbalances the telescope and cameras. The circles have white figures on black background, being easier to read in the dark than black figures on a white ground. The declination-circle is graduated to 30′ and reads by verniers to 2′. The hour-circle is graduated to 4^m and reads by verniers to 20^s. These graduations are fine enough for setting purposes.

A flat iron bed-plate 1 ft. x 2 ft. takes the place of the usual saddle on the end of the declination-axis to which the telescope is fastened. On it a wooden platform 2 ft. x 3 ft. is firmly fastened. The guiding telescope, a 3½-inch Mogey refractor, is fastened to one side of the under surface of this wooden platform, and a balance weight is fastened to the other side. This leaves the upper surface free for screwing on one or more cameras. This platform is a temporary expedient for the purpose of testing various cameras; later the cameras will be fastened directly to the bed-plate.

The polar-axis bearings are conical, and the weight is taken off the upper bearing by a pair of counter friction-wheels suspended in a frame-work which is pulled up by a strong adjustable steel spring. The end-thrust of the polar axis is taken up by an adjustable ball-bearing at the lower end. All those parts of the instrument that may wear or work loose are adjustable, so that lost motion may always be prevented. For example, in the declination slow motion provision is made for taking up lost motion in three directions, so that this very important adjustment can never wear loose.

A few words regarding the photographic lens: it is a C. C. Harrison portrait combination of about 5½ inches aperture and about 22 inches equivalent focus. The camera carries a 6½ x 8½ plate, but the field of view, where the star disks are quite sharp, is limited to about 10 centimeters square,

or about 10° square. An exposure of about twenty minutes on a good night will give impressions of stars of about 11th or 12th magnitude and good measurable images of 10th magnitude stars. As an example of the work possible with this lens, on December 29, 1902, with the camera strapped on the 6-inch equatorial, an exposure was made for 1^h 13^m of the region around asteroid (385) 10.1 magnitude, and a distinct trail was found very near the computed position of the asteroid.

A description of the photographic equatorial would not be complete without mentioning those connected with its construction. The heavy castings and their patterns were made by the California School of Mechanical Arts; the heavy machine work is by the J. A. Gray Machine Co.; the composition castings are by the Eureka Foundry; and the circles were graduated by the A. Lietz Co.; all of San Francisco. All other parts of the instrument were constructed by Mr. VALDEMAR ARNTZEN, of the Department of Civil Engineering. He has done all of the finer instrumental work, and also helped in solving several knotty problems in the designing.

No work has been done as yet with this instrument; but it is hoped that it will be possible in the near future to present to the Society a satisfactory report of its work.

A FEW DETAILS OF THE TWELVE-YEAR SUN-SPOT CYCLE.

By ROSE O'HALLORAN.

Though regularity in the increase and decline of solar activity first led to a recognition of sun-spot periods, still each cycle of change has its individual traits, tendencies, and occasional discrepancies. The cause of periodicity being entirely unknown, such details are of interest, as they may be more than unimportant casualties. The following brief summary of observations from November 1, 1891, to November 1, 1903, contains some of the characteristics of the prolonged cycle that occurred between these dates. According to Professor WOLFER'S revision of sun-spot data, a marked minimum took place early in 1890. This extreme stage of unspottedness did